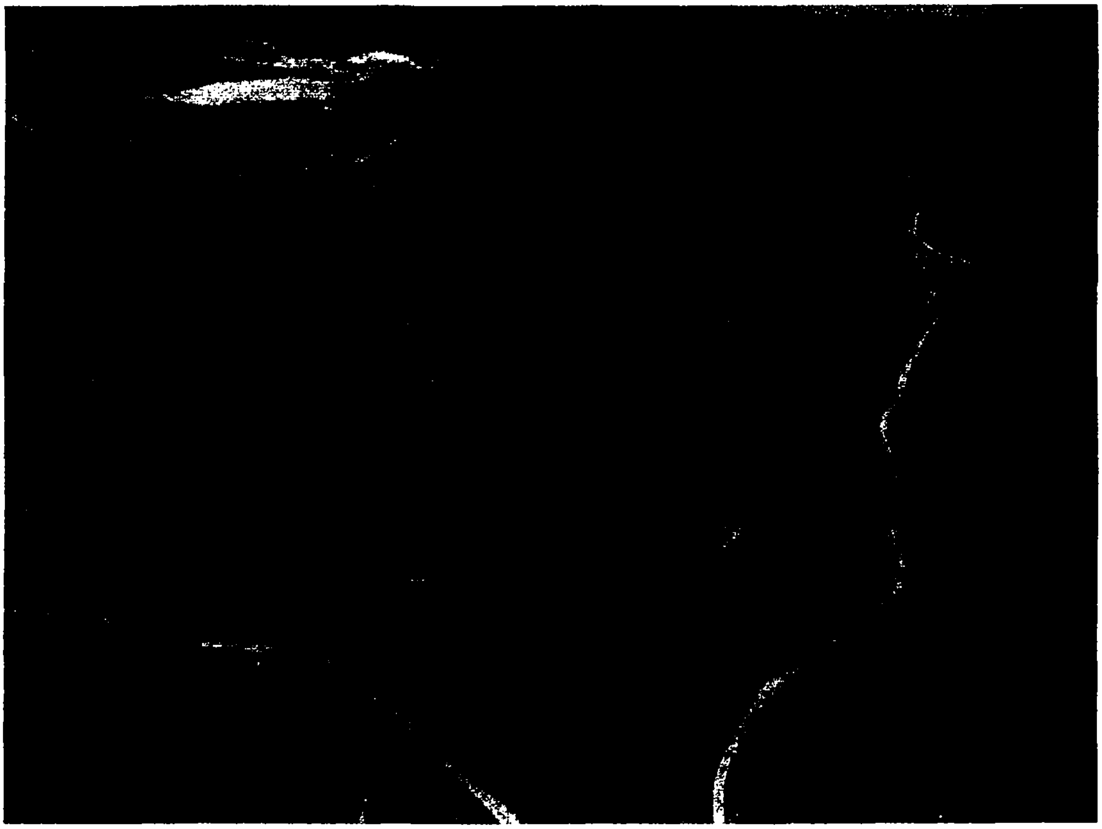
DRAFT FINAL – FOR EPA REVIEW AND COMMENT ONLY

PROBLEM FORMULATION FOR ECOLOGICAL RISK ASSESSMENT AT OPERABLE UNIT 3 LIBBY ASBESTOS SUPERFUND SITE



May 1, 2008

Prepared by:
US Environmental Protection Agency
Region 8
Denver, CO

With Technical Assistance from:
Syracuse Research Corporation
Denver, CO

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LIST OF ACRONYMS

BTAG	Biological Technical Assistance Group
cc	Cubic Centimeter
cfs	cubic feet per second
COC	Chain of Custody
COPC	Chemicals of Potential Concern
CSM	Conceptual Site Model
DO	Dissolved Oxygen
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EDS	Energy Dispersive Spectroscopy
FS	Feasibility Study
GI	Gastrointestinal
GRAV	Gravimetric
ha	hectare
HQ	Hazard Quotient
HQmax	Maximum Hazard Quotient Value
IMEE	In-Situ Measures of Exposure and Effects
ISO	International Organization for Standardization
KDC	Kootenai Development Corporation
LA	Libby Amphibole
MDEQ	Montana Department of Environmental Quality
MFL	Million Fibers per Liter
MMU	Minimum Map Unit
MNHP	Montana National Heritage Program
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDO	Population and Community Demographic Observations
PCM	Phase Contrast Microscopy
PEC	Probably Effect Concentration
PLM	Polarized Light Microscopy
PLM-VE	Polarized Light Microscopy Visual Area Estimation Method
PLM-PC	Polarized Light Microscopy Point Count Method
RBP	Rapid Bioassessment Protocol
RI	Remedial Investigation
SAED	Selective Area Electron Diffraction
SAP	Sampling and Analysis Plan
SEM	Scanning Electron Microscopy
SOP	Standard Operating Procedure
SSTT	Site-Specific Toxicity Tests

LIST OF ACRONYMS (cont.)

SVOC	Semi-Volatile Organic Chemical
TEC	Threshold Effect Concentration
TEH	Total Extractable Hydrocarbons
TEM	Transmission Electron Microscopy
TPH	Total Petroleum Hydrocarbons
TM	Thematic Mapper
TRV	Toxicity Reference Value
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile Organic Chemical
VPH	Volatile Petroleum Hydrocarbons
WHO	World Health Organization

1.0 INTRODUCTION

This document is an initial Problem Formulation for the ecological risk assessment (ERA) that will be performed for Operable Unit 3 (OU3) of the Libby Asbestos Superfund Site located near Libby, Montana.

Problem formulation is a systematic planning step that identifies the major concerns and issues to be considered in an ERA, and describes the basic approaches that will be used to characterize ecological risks that may exist (USEPA 1997). As discussed in USEPA (1997), problem formulation is generally an iterative process, undergoing refinement as new information and findings become available (Figure 1-1).

The first step in the ecological problem formulation is the review of available information on the nature of the site and the ecological setting, the nature of the contaminants that may be present in environmental media, and the types of ecological organisms that may come into contact with contaminated media. This information is summarized in Section 2 of this document.

The next step is to utilize the information that is available to develop one or more Conceptual Site Models (CSMs), which summarize the understanding of contaminant sources, fate and transport pathways, and exposure pathways that are potentially relevant for each group of ecological receptors. This information is presented in Section 3 of this document. As noted above, the CSM may be refined in an iterative process as new information becomes available.

The next step in problem formulation is to identify the risk management objectives at the site, and to select approaches for assessing whether those objectives are achieved or not. Section 4 of this document presents the risk management goals for the site, and reviews the general strategies that are available to assess risks to ecological receptors.

Section 5 reviews the strategies that are available for evaluation of risks to ecological receptors from non-asbestos contaminants that may be present at the site. Section 6 presents an evaluation of the strategies that are available for evaluating ecological risks from asbestos. Final decisions regarding which strategies will be implemented are not presented in this Problem Formulation Document. Rather, final decisions about which strategies will be implemented, and in what sequence, will be presented in subsequent sampling and analyses plans (SAPs).

2.0 SITE CHARACTERIZATION

2.1 Site Location

Libby is a community in northwestern Montana that is located near a large open-pit vermiculite mine. The mine location and preliminary study area boundary of Operable Unit (OU) 3 are shown in Figure 2-1. EPA established this preliminary study area boundary for the purpose of planning and developing the initial scope of the RI/FS for OU3. This preliminary boundary may be revised as results from the RI clarify the extent of environmental contamination associated with releases that may have occurred from the mine site.

2.2 Physical Setting

Land Use

The terrain in OU3 is mainly mountainous with dense forests and steep slopes. Current land ownership in the area is shown in Figure 2-2. Kootenai Development Corporation (KDC), a subsidiary of W.R Grace & Co., owns the mine area and the immediately adjacent portion of the off-mine area. The majority of the surrounding land is owned by the United States government and is managed by the Forest Service, with some land parcels owned by the State of Montana and some owned by Plum Creek Timberlands LP for commercial logging.

Climate

Northern Montana has a climate characterized by relatively hot summers, cold winters, and low precipitation. Table 2-1 presents climate data collected at the Libby NE Ranger Station, which is located just west of the town of Libby near the Kootenai River. Average summer high temperatures (^{o}F) are in the upper 80s, and low temperatures are in the 40s, while winter highs are in the 30s and lows are in the teens. The western mountain ranges cause Pacific storms to drop much of their moisture before they reach the area, resulting in relatively low precipitation, averaging about 18 inches per year. The most abundant rainfall occurs in late spring/early summer. In the winter months, snowfall averages 54 inches each year and snow cover typically remains on the ground from November through March. Data collected from a weather station at the mine site indicate that winds are predominantly to the northeast (Figure 2-3).

Surface Water Features

The mine is located within the Rainy Creek watershed, which includes Rainy Creek, Carney Creek and Fleetwood Creek (Figure 2-4). The area drained is approximately 17.8 square miles.

Rainy Creek

Rainy Creek originates between Blue Mountain and the north fork of Jackson Creek at an elevation of about 5,000 feet, and falls to an elevation of 2,080 feet at the confluence with the Kootenai River (Zinner 1982). The average gradient for Rainy Creek is about 12% (Parker and Hudson 1992), and the banks are well vegetated (MWH 2008).

Fleetwood and Carney Creeks

Fleetwood Creek and Carney Creek are tributaries to Rainy Creek (Figure 2-4). The average stream gradient for Fleetwood Creek is about 11% (Parker and Hudson, 1992). Under current site conditions, Fleetwood Creek flows through a portion of mine waste before flowing into a large tailings impoundment which was constructed within the former Rainy Creek channel (see below). A ponded area was identified along Fleetwood Creek during reconnaissance surveys by EPA in 2007. This area is devoid of vegetation (Figure 2-9).

Carney Creek flows along and through mine waste on the south side of the mined area before joining Rainy Creek. During an aerial survey in 2008, a small pond was discovered on Carney Creek (Figure 2-9). This pond was formed when waste piles were deposited in the drainage and blocked and altered the flow of the creek. The pond is vegetated on one side. Several small springs are reported along Carney Creek (Zinner, 1982) and were identified during reconnaissance surveys by EPA in 2007 (Figure 2-9).

Tailings Impoundment

In 1972, W.R. Grace & Co. constructed a tailings impoundment that received the discharge of process waters that had previously been directly discharged to Rainy Creek. The impoundment was built to provide for settlement of the fine tails produce by the new (wet) process and to recover water for reuse. The height of the dam which forms the impoundment is about 135 feet measured from the downstream toe. The impoundment occupies 70 acres (Figure 2-5).

The impoundment receives input from both upper Rainy Creek and Fleetwood Creek (Figure 2-4). The impoundment drains through a toe drain directly into Rainy Creek, and may also discharge to Rainy Creek via an overflow channel during high flow events (Parker and Hudson, 1992).

Mill Pond

A pond in the Rainy Creek channel downstream of the tailings impoundment was constructed to provide a water supply for mining operations. The pond discharges to Rainy Creek where it mixes with flow from Carney Creek and flows downstream to the Kootenai River. This reach has some seasonal gain in flow, most likely due to groundwater input (USEPA, 2007).

Kootenai River

The Kootenai River flows from east to west along the south side of the site. Flows in the Kootenai River are controlled by the Libby Dam, which was constructed in the late-1960s and early-1970s as part of the Columbia River development for flood control, power generation, and recreation. Daily water outflow plans[1] for October 2006 through August 2007 show lowest discharge flows in March and October at approximately 4,000 cubic feet per second (cfs) and maximum discharge flows in late May/early June at 26,600 cfs.

State Water Use Designations

Table 2-2 presents designated uses for Rainy Creek and the Kootenai River near and downstream of the mine area, as classified by the State of Montana Administrative Rules Chapter 30 Water Quality Subchapter 5 (§17.30.609) for the Kootenai River drainage. The State of Montana has established numeric standards for the protection of aquatic life and human health associated with the designated uses. The numeric standards are set forth in the Montana Department of Environmental Quality Circular DEQ-7 – Montana Numeric Water Quality Standards.

<u>Occurrence and Nature of Asbestos at the Mine</u>

The mine is located in a region of the Precambrian Belt Series of northwestern Montana that has been intruded by an alkaline-ultramafic body. The Rainy Creek Igneous Complex comprises the upper portion of this intrusion. Hydrothermal alteration of the biotite pyroxenite intrusion produced the large, high-quality vermiculite deposit. The vermiculite content of the ore varies considerably within the deposit, ranging from 30 to 84%.

Fibrous and asbestiform amphiboles are present in association with the vermiculite ore (see Section 6.1 for more information on asbestos mineralogy). A significant portion of the fibrous amphiboles are located along cross-cutting veins and dikes and in the altered pyroxenite wall rock adjacent to them. The alteration zones, dikes, and veins that range in width from a few millimeters to meters in thickness are found throughout the deposit. Amphibole content in the alteration zones of the deposit is estimated to range between 50-75%. The U.S. Geological Survey (USGS) performed electron probe micro-analysis and X-ray diffraction analysis of 30 samples obtained from the exposed asbestos veins to identify the type of amphibole asbestos present in the mine (Meeker et al. 2003). The results indicated that a variety of amphiboles exist at this site, including winchite, richterite, tremolite, actinolite, and magnesioriebeckite. The EPA refers to this mixture of amphibole asbestos minerals as Libby Amphibole Asbestos(LA).

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[1] Available from http://www.nwd-wc.usace.army.mil/ftppub/project_data/yearly/lib_wy_qr.txt

Historic Mine Operations and Current Features

Figure 2-5 shows the current mine features and location of historical mining operations. The mine was operated from 1923 until 1990 and was open pit except for a short period in the early period of operations. The mine area is heavily disturbed by past mining activity and some areas remain largely devoid of vegetation. There are a number of areas where mine wastes have been disposed (Figure 2-5), including waste rock dumps (mainly on the south side of the mine), coarse tailings (mainly to the north of the mine), and fine tailings (placed in the tailings impoundment on the west side of the site).

The basics of ore processing did not change over the period of operation, although unit operations were changed as ore quality decreased and technology improved, and in response to concerns over dust generation (Zucker, 2006). In general, rock was removed to allow access to the vermiculite or separated from the vermiculite in the mine pits and dumped over the edge to form waste rock piles (see Figure 2-5). After 1971, ore was processed to separate out vermiculite product by crushing, screening or water floatation, with those operations generally occurring in the mill area (Figure 2-5).

A storage and loading facility along the river at the mouth of Rainy Creek was built in 1949. It included a 600-foot conveyor belt for carrying material across the Kootenai River, and a loading facility along the Great Northern Railroad tracks on the south side of the river.

A new concentrating plant began operations in 1954 in the general milling area (Figure 2-5). This plant was designed to separate the vermiculite from ore that contained less than 35% vermiculite. Continued refinements led to implementation of a wet process, in which a froth flotation process was coupled with shaking tables to separate waste rock from the vermiculite. The dry mill continued to operate. After passing through a two-inch grizzly, ore went to one of five storage bins at the mill. Ore was blended and sent to the primary screens at the mill where water was added. Oversize material was concentrated in jigs and dried in rotary driers. The material was then crushed using hammer mills and roll crushers before being screened, with finer material further separated using spiral concentrators. Material was then dewatered and dried before being screened for product. The process generated two types of waste material; coarse tailings which were disposed in a pile to the north (Figure 2-5) and fine tailings which appear to have been discharged to Rainy Creek until a tailings impoundment was constructed in 1971.

W.R. Grace & Co.-Conn. (then known as W.R. Grace & Co.) took over mining in 1963. In 1971, they undertook a major expansion to increase capacity and improve the beneficiation process. It was at this time that the tailings impoundment was built to provide for settlement of the fine tailings produced by the new process and to recover water for reuse (Schafer, 1992). The dam was designed and constructed in stages, with a 50 foot high starter dam constructed in 1971, immediately downstream of an older, existing dam. Additional construction phases in 1975, 1977, and 1980 raised the top of the dam to a total height of 135 feet measured from the downstream toe.

Remedium reviewed historic information on mining operations at the site and reported that in a typical year about 5 million tons of rock was mined to generate 220,000 tons of vermiculite product. Primary waste materials were waste rock (3.5 million tons per year) and tailings (1.1 million tons per year), with lesser amounts of oversize rock and screening plant concentrate wastes. As higher quality ores were depleted and lesser quality ores were mined, various reagents were used to facilitate the separation. Reported reagents include #2 Diesel Fuel (typically between 1.2 and 5.4 million pounds per year), Armeen T (Tallow Alkyl Amine; 100,000 to 500,000 pounds per year), fluorosilicic acid (50,000 to 240,000 pounds per year) and lesser quantities of flocculants, defoamers, frothers and other reagents.

2.3 Ecological Setting

2.3.1 Terrestrial Habitats and Plant Species

Most of OU3 is forested, with only 4% of the land being classified as non-forest or water (USDAFSR1, 2008; Figure 2-6). Data for the National Forest indicate Douglas-fir forest type is the most common, covering nearly 35 percent of the National Forest land area. Next in abundance are the lodgepole pine forest type and spruce-fir forest type at 17 percent each, and the western larch forest type at 11 percent. Other species reported in the area are the Black Cottonwood (*Populus trichocarpa*), Quaking Aspen (*Populus tremuloides*), Western Paper Birch (*Betula papyrifera var. occidentalis*) and Pacific Yew (*Taxus brevifolia*) (USDAFSR1, 2008).

Specific vegetative surveys of the Libby OU3 mine site are not available. Therefore, an initial vegetative cover map was created using existing information from the analyses of remote sensing data. In 1998, the Wildlife Spatial Analysis Lab at the University of Montana in Missoula created the *Montana Land Cover Atlas* as part of the Montana Gap Analysis Project (Fisher et al., 1998). Data from this project classifies 50 land cover types. The group developed the classification based on the hierarchical design of Anderson et al. (1976) in the same manner as was accomplished in Wyoming (Merrill et al. 1996). Land cover types were targeted and defined according to known occurrences in the state and from classifications used for GAP projects in both Idaho (Caicco et al. 1995) and Wyoming (Merrill et al., 1996). The final list of 50 land cover types is shown in Table 2-3. Vegetative cover on and in the vicinity of the Libby OU3 Site is provided as Figure 2-7. The map is generated from Landsat Thematic Mapper (TM) data covering Montana. Upland cover types were mapped to 2 hectare (ha) minimum map unit (MMU). Based on this mapping, the vegetative cover around the mine site is predominantly Douglas-fir, lodgepole pine and mixed mesic forest.

2.3.2 Aquatic Species

Rainy Creek Watershed

Within the Rainy Creek watershed there are streams and ponds that provide habitat for aquatic species including plants, invertebrates, amphibians, and fish. The U.S Forest Service has compiled data on the species and genetic type of fish in Rainy Creek, but EPA has not yet been able to access these data.

The Montana National Heritage Program (MNHP) lists 25 species of fish that are expected to occur in the area. Of these 12 are considered to be possible inhabitants of waters in the Rainy Creek watershed. These species include brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), Columbia River redband trout (*Oncorhynchus mykiss gairdneri*), fathead minnow (*Pimephales promelas*), largescale Sucker (*Catostomus macrocheilus*), longnose dace (*Rhinichthys cataractae*), longnose sucker (*Catostomus catostomus*), mottled sculpin (*Cottus bairdi*), mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), torrent sculpin (*Cottus rhotheus*), and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). The Montana Fish Wildlife and Parks reports that the westslope cutthroat trout is a year round resident in both upstream Rainy Creek and upstream Carney Creek.

It is possible that some of the ponds and impoundments in the Rainy Creek watershed might support some other species of fish that are not expected to occur in high grade mountain streams, but no data have been located on this issue.

Kootenai River

EPA's Environmental Monitoring and Assessment Program (EMAP) has collected aquatic community data at a station on the Kootenai River about one mile downstream of the confluence with Rainy Creek. This location was sampled in August 2002. Forty-four species of aquatic invertebrates have been observed, including oligocheates, insects (diptera, ephemeroptera, trichoptera and hemiptera), colenterates (hydra), mollusks, and nematodes (see Table 2-4). Eleven species of fish were observed (Table 2-5). Mountain whitefish were most common, along with several species of salmonids (rainbow trout, sockeye salmon, cutthroat trout, bull trout) and several species forage fish (dace, shiner, sculpin)..

2.3.3 Wildlife Species on or Near the Libby OU3 Site

The Montana Natural Heritage Program is a source for information on the status and distribution of native animals and plants in Montana. An assessment of which wildlife species are expected to occur at the Libby OU3 site was performed based on the Montana Natural Heritage Program Animal Tracker (http://nhp.nris.mt.gov/Tracker/). First, all species known to occur within Lincoln County, Montana, were identified. Next, the Montana Natural Heritage Program and Montana Fish, Wildlife and Parks Animal Field Guide (http://fieldguide.mt.gov/) was consulted to identify if a particular species was observed near the Libby OU3 Site. Species not identified within the vicinity of OU3, and those not expected to occur at OU3 based on a consideration of available habitat, were removed. The species that remained are listed in Attachment A, along with information on general habitat requirements, habitat type for foraging and nesting, feeding guild, typical food, migration and hibernation, longevity, home range and size. The oldest recorded sighting and latest (year), and the number of individuals identified was also recorded.

The species identified as residing within Libby OU3 include 29 invertebrates (26 terrestrial and 3 aquatic), 24 fish, 7 amphibians, 7 reptiles, 175 birds, and 48 mammals.

2.3.4 Federal and State Species of Special Concern

There are six federally listed protected species that have been reported to occur in or about the vicinity of the Libby OU3 Site, including 2 fish, 1 bird, and 3 mammals. These are listed in Table 2-6. Species of concern to the State of Montana that have been observed to occur in the vicinity of Libby OU3 Site are listed in Table 2-7. This includes 2 amphibians, 7 birds, 4 mammals, 3 fish, and 7 invertebrates. However, not all of these species are equally likely to occur within the OU. Based on an evaluation of frequency of observation , the following listed species are considered to be the most likely to be present in the OU:

- Coeur d'Alene Salamander (*Plethodon idahoensis*)
- Boreal Toad, Green (also known as Western Toad) (*Bufo boreas*)
- Flammulated Owl (*Otus flammeolus*)
- Northern Goshawk (*Accipiter gentilis*)
- Bull Trout (*Salvelinus confluentus*)
- Torrent Sculpin (*Cottus rhotheus*)
- Westernslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*)
- White Sturgeon (*Acipenser transmontanus*) (Kootenai River Pop.)

2.4 Summary of Data Available from Phase I

In 2007, EPA began performance of a Remedial Investigation (RI) for Libby OU3. The RI began by collection of an initial round (referred to as Phase I) of environmental samples of a variety of media (surface water, sediment, on-site and off-site soils, tree bark) in the fall of 2007. These samples were analyzed for LA and/or a range of non-asbestos analytes. The raw data from the Phase I investigation are presented in Attachment B and are summarized below.

2.4.1 Asbestos

Surface Water and Sediments

Surface water and sediment samples were collected during the Phase 1 investigation at a total of 24 locations, as shown in Figure 2-8. Figure 2-9 provides color photos of a number of the sampling stations.

Surface water were analyzed for LA by Transmission Electron Microscopy (TEM) using Modified EPA Method 100.2 (USEPA, 1994) in accord with the modified counting procedures described in Libby Laboratory Modification LB-000020 (USEPA, 2007). Table 2-8 summarizes the results of the analysis of surface water for asbestos (LA). Results are expressed in terms of million fibers per liter (MFL). The results are also mapped in Figure 2-10 to show the spatial pattern of results. The highest levels were observed in samples located in ponds or impoundments, including the tailings impoundment, the mill pond, and the pond on Fleetwood creek, as well as from several seeps along the south side of the mined area. Levels in lower Rainy Creek (below the mill pond) are relatively lower.

Sediment samples were prepared for LA analysis by sieving into coarse (> ¼ inch) and fine fractions. The fine fraction was ground to reduce particles to a diameter of 250 um or less and separated into 4 aliquots. The coarse fraction soil aliquot (if any) was examined using stereomicroscopy, and any particles of asbestos (confirmed by PLM) were removed and weighed. The fine ground fraction was analyzed by PLM visual area estimation method (PLM-VE) using Libby-specific reference materials in accordance with SRC-LIBBY-03 Revision 2. Results from the PLM-VE method are semi-quantitative, with an estimated detection limit for LA of about 0.2% or slightly less.

The results of the analyses of the fine and coarse fractions of the sediments are shown in Table 2-9. The results are also mapped in Figure 2-11 to show the spatial pattern of results. Results for LA in sediment are expressed as mass percent (grams of asbestos per 100 grams of soil) if the concentration is 1% or higher. If the estimated concentration is <1%, the results are expressed semi-quantitatively, according to the following scheme:

PLM-VE Result	Range of Mass Percent
A (ND)	None detected (likely < 0.05%)
B1 (Trace)	LA detected, > 0% but < 0.2%
B2 (<1%)	LA detected, >0.2% but < 1%

Nearly all (22 out of 24) of the sediment samples collected contain LA. Of these, one is classified as Bin B1 (<0.2%), 12 are classified as Bin B2 (about 0.2 to 1%), and 9 were estimated to contain levels from 2-7%. These results indicate that asbestos in sediment is widespread throughout the surface water features draining the site, and that levels are substantial in many locations.

Mine Wastes and Soils

Figure 2-12 shows the locations of the mine waste and/or soil samples. The Phase I samples focused on each of the principal mine waste materials identified to date including mine waste rock, impounded tailings, and coarse tailings as well soils in the former mill area and soils in the former mill area; and materials used for construction of unpaved sections of Rainy Creek Road.

Soil samples collected for asbestos analysis were prepared and analyzed in the same manner as previously described for sediments. Table 2-10 summarizes the results of the analysis of the fine fraction of mine waste and soil samples for LA. All but one soil sample (33 of 34) contained LA. Of these, two are classified as Bin B1 (<0.2%), 26 are classified as Bin B2 (0.2% to 1%), and 5 are estimated to contain levels from 2-8%.

Tree Bark

During Phase 1, samples of bark from trees at least 30 years old were collected at a number of stations located on transects that radiate away from the mine, with special emphasis on the predominant downwind direction (northeast) (Figure 2-13). All tree bark samples were collected from the side of the tree facing toward the mine site, from a height of about 4-5 feet above ground. The tree bark samples were ashed and analyzed for LA by TEM. Results are expressed as LA fibers per cm^2 of tree bark. Results are shown in Figure 2-14 As seen, although there is moderate spatial variability, there is a general tendency for the highest levels (> 2.5 million fibers per cm^2) to occur within about 2 to 3 miles of the mined area, with a tendency for values to diminish as a function of distance from the mine. Elevated values are noted not only in the downwind direction (north-northeast from the mine), but also along nearly all transects. ~~It is suspected that the majority of the LA in tree bark is attributable to historic releases to air during the time the mine was active~~, although current and on-going releases may also be contributing.

Forest Soil, and Duff

Forest soil and duff samples were collected from approximately equally spaced locations around the perimeter of a circle with a radius of about 5 feet, centered on the same tree where the bark sample was collected (see Figure 2-13). The grab samples were combined into one composite and analyzed for asbestos as previously described for mine waste and soils.

The soil samples were analyzed for LA by PLM-VE. The results are provided in Table 2-11 and are plotted in Figure 2-15. As seen, LA was detectable in a number of soil samples located relatively close to the mined area, but was not detectable at a distance more than about 2 miles from the mined area. The source of the LA observed at these locations is unknown, but might include a) naturally occurring outcrops of the LA-bearing ore body, b) deposition from historic airborne releases from the mine and mill, and c) water-based erosion from past and/or present materials at the mine site. ~~If current levels of LA are found to be~~ of ecological concern, EPA will seek to ~~collect information~~ to allow an estimation of the relative contribution of anthropogenic and natural sources of LA. — Fosh might?

The full results of the duff samples are not yet available, but preliminary data suggest that LA is observable in duff samples near the mine.

Ambient Air

The purpose of the Phase I ambient air sampling was to obtain data on the level of releases occurring from the mine ~~area to adjacent downwind areas~~ under current site conditions. The basic sampling design for ambient air consists of two concentric rings of stationary air monitors placed around the mine. The first ring is close to the boundary of the disturbed area, and the second ring is close to the perimeter of the property owned by KDC. Figure 2-16 shows the locations for the ambient air monitors. Each sample was collected over a period of 5 days, with samples being collected once per week for a period of four weeks. All air samples were analyzed for asbestos by TEM in accord with the ISO 10312 method (ISO 1995) counting protocols, with all applicable Libby site-specific laboratory modifications, including the most recent versions of modifications as specified in the SAP (USEPA, 2007).

The results of analyses of asbestos in the ambient air samples are provided as Table 2-12. Asbestos was not detected in any of the field samples. These results should be interpreted cautiously because ambient air samples were collected over a time interval when rain was occurring frequently, which may have reduced the potential for airborne releases to ambient air.

2.4.2 Non-Asbestos Contaminants

Surface Water

Surface water samples were collected during the Phase 1 investigation at a total of 24 locations, as shown in Figure 2-8. The surface water samples collected during Phase I were analyzed for metals and metalloids, petroleum hydrocarbons, anions, and other water quality parameters. In addition, several selected surface water samples were analyzed for a broad suite of other chemicals. Table 2-13 lists the analytical methods and analyses for the Phase I samples. Table 2-14 shows the analyses that were performed for each sampling location. In addition to laboratory analyses, surface water samples were analyzed in the field for surface water quality parameters. Surface water flow was also measured at each sampling location.

The results of the analyses of Phase I surface water samples for non-asbestos analytes are provided in Table 2-15. The analytes listed in the table are those that were detected in at least one surface water sample. The results of water quality parameters measured in the field are provided in Table 2-16. Flow measurements are provided in Table 2-17. Nine metals were detected as well as benzene, aliphatic hydrocarbons, total petroleum hydrocarbon (TPH), total extractable hydrocarbons (TEH), nitrate, nitrite, chloride, fluoride, sulfate, and phosphate. Volatile organic chemicals (VOCs), semi-volatile organic chemicals (SVOCs), polychlorinated biphenyls (PCBs), pesticides and polycyclic aromatic hydrocarbons (PAHs) were not detected in any of the surface water samples.

Sediment

Sediment water samples were collected during the Phase 1 investigation at a total of 24 locations, as shown in Figure 2-8. All sediment samples were analyzed for asbestos, metals and metalloids, petroleum hydrocarbons, and several sediment quality parameters. In addition, several selected sediment samples were analyzed for a broad suite of other chemicals. Table 2-18 lists the analytical methods that were employed, and Table 2-19 shows the analyses that were performed at each station.

The results of the analyses of the Phase I sediment samples are provided in Table 2-20. The analytes listed in the table are those that were detected in at least one sediment sample. The full results of the analyses are included in Attachment B. Fifteen metals were detected as well as pyrene, methyl acetate, aromatic and aliphatic hydrocarbons, TEH, and TPH. Figure 2-17 displays the results for chromium, and Figure 2-18 displays the results for TPH. Other analytes, including PCBs, SVOCs and pesticides, and were not detected in any of the sediment samples.

On-Site Soil and Mine Waste

Figure 2-12 shows the locations of the on-site mine waste and/or soil samples collected during Phase I. These samples focused on each of the principal mine waste materials identified to date including mine waste rock, impounded tailings, and coarse tailings as well soils in the former mill area and soils in the former mill area; and materials used for construction of unpaved sections of Rainy Creek Road. These samples are divided into six categories:

Road	MS-1 to MS-2
Tailings Impoundment	MS-4 and M-5
Coarse Tailings	MS-6 to MS-9
Cover Material	MS-10 to MS-13; MS-21 to MS-24
Waste Rock	MS-14 to MS-20; MS-26 to MS-30; MS-32
Outcrop	MS-25; MS-31; MS-33-38

All mine waste and soil samples were analyzed for asbestos, metals and metalloids, petroleum hydrocarbons, as well as pH, moisture content and organic carbon content. This was with the exception of outcrop samples which were not analyzed for petroleum hydrocarbons. In addition, several selected mine waste and soil samples were analyzed for a broad suite of other chemicals. Table 2-21 lists the analytical methods that were used, and Table 2-22 shows the analyses that were performed at each sampling location.

The results of the analyses of the Phase I mine waste and soil samples are provided in Table 2-23. The results listed in the table are those for analytes that were detected in at least one mine waste or soil sample. The full results of the analyses from the Phase 1 sampling program are included in Attachment B. Fifteen metals, eight PAHs, one pesticide (pentachlorophenol), one

VOC (methylacetate), aromatic and aliphatic hydrocarbons, TEH, toluene and TPH were detected. PCBs and SVOCs were not detected in any of the mine waste and soil samples.

3.0 CONCEPTUAL SITE MODELS

After review of available information on the site, the ecological setting and the nature of contaminants that may be present, the next step in problem formulation for an ecological risk assessment is the development of a Conceptual Site Model (CSM). The CSM is a schematic summary of what is known about the nature of source materials at a site, the pathways by which contaminants may migrate through the environment, and the scenarios by which receptors may be exposed to site-related contaminants. When information is sufficient, the CSM may also indicate which of the exposure scenarios for each receptor are likely to be the most significant, and which (if any) are likely to be sufficiently minor that detailed evaluation is not needed.

Figure 3-1 presents the CSM for exposure of each general ecological receptor group (fish, benthic invertebrates, terrestrial plants, soil invertebrates, birds and mammals and amphibians) to non-asbestos mining-related contaminants. As seen, each receptor group may be exposed by several different pathways. However, not all pathways are equally likely to be important. In each CSM, pathways are divided into three main categories:

- A solid black circle (●) represents pathways that are believed to be complete, and which may provide an important contribution to the total risk to a receptor group.
- An open circle (O) represents an exposure pathway that is believed to be complete, but which is unlikely to be a major contributor to the total risk to a receptor group, at least in comparison to one or more other pathways that are evaluated.
- An open box represents an exposure pathway that is believed to be incomplete (now and in the future). Thus, this pathway is not assessed.

Figure 3-2 presents the CSM for exposure to asbestos. This CSM is similar to the one for non-asbestos (Figure 3-1), except that information is not generally available to characterize the relative importance of each of the various pathways by which a receptor may be exposed. For this reason, the open circle is only used for direct contact (dermal exposure) of birds and mammals with asbestos. However, it should still be understood that not all of the exposure pathways indicated by a black circle for a receptor are likely to be of equal concern.

The following sections provide a more detailed discussion of the main elements of these CSMs.

3.1 Potential Sources of Contamination

The main sources of asbestos contamination at this site are the mine wastes generated by historic vermiculite mining and milling activities. This includes piles of waste rock and waste ore at on-site locations, as well as the coarse tailings pile and the fine tailings impoundment. These wastes may also be sources of metals and other inorganic constituents of the ore. In addition, some chemicals used at the mine site in the processing of vermiculite ore might also be present in onsite wastes, including diesel fuel, alkyl amines, fluorosilicic acid, and various other flocculants, defoamers, frothers and other reagents.

3.2 Migration Pathways in the Environment

From the sources, contaminants may be released and transported via airborne emissions, surface water transport or food chain transport.

Airborne Transport. Contaminants may become suspended in air and transported from sources via release mechanisms such as wind, mechanical disturbances and/or erosion. Once airborne, contaminants may move with the air and then settle and become deposited onto surface soils. This pathway is likely to be important for asbestos, but is thought to be of low concern for non-asbestos contaminants.

Surface Transport. Contaminants may be carried in surface water runoff (e.g., from rain or snowmelt) from the mine or other areas where soil is contaminated, and become deposited in soils or sediments at downstream locations. This pathway is equally applicable to both asbestos and non-asbestos contaminants.

Food Chain Transport. Contaminants may be taken up from water, sediment or soil into the tissues of aquatic or terrestrial organisms from water and/or sediment and/or soils and/or prey items into prey items (fish, benthic invertebrate, plants, soil invertebrates, birds, mammals). This is applicable to both asbestos and non-asbestos contaminants.

3.3 Potentially Exposed Ecological Receptors

As discussed in Section 2.3, there are a large number of ecological species that are likely to occur in OU3 and that could be exposed to mine-related contaminants. However, it is generally not feasible or necessary to evaluate risks to each species individually. Rather, it is usually appropriate to group receptors with similar behaviors and exposure patterns, and to evaluate the risks to each group.

For aquatic receptors, organisms are usually evaluated in two groups:

- Fish
- Benthic macroinvertebrates

For terrestrial receptors, organisms are usually grouped into five broad categories:

- Plants
- Soil invertebrates
- Birds
- Mammals

- Amphibians

Screening assessment usually begins by assessing risks to each group as a unit, using a sensitive member of the group as an indicator species. In cases where risks appear to be above a level of concern for a large group (e.g., birds, mammals), it may sometimes be useful to divide the groups into smaller sub-groups to allow a more refined assessment. For example, when needed, birds and mammals may be stratified into a number of feeding guilds. Based on the information regarding the types of birds and mammals that are present at this site, the following feeding guilds may be useful if a refined assessment is required for an assessment of wildlife populations at the site.

- *Invertivorous Wildlife* – Invertivorous wildlife consume primarily soil invertebrates and are important in nutrient processing and energy transfer within the terrestrial environment. Insectivorous birds and bats are also important in the control of populations of emerging aquatic insects. These animals also are important food sources for other mammals and birds (carnivores). This group of receptors can be further subdivided according to where and how the organism feeds on invertebrates. Some avian species are *aerial invertivores* feeding on insects in flight. Other avian and mammalian species feed primarily on invertebrates in trees (*arboreal insectivores*).

- *Herbivorous Wildlife* – Herbivorous wildlife consume primarily plant material and are important in nutrient processing and energy transfer within the terrestrial environment. Small herbivorous mammals are important food resources for other mammals and birds (carnivores). This group of receptors can be further subdivided into those species that consume primarily fruit (*frugivores*), nectar (*nectaravores*), or grain (*grainivores*). In particular, avian species that consume nectar are important in the pollination of plants. Granivorous mammals and birds are important in the dispersal of plants as well as nutrient processing and energy transfer. They also serve as food resources for other mammals and birds (*carnivores*).

- *Omnivorous Wildlife* – Omnivorous wildlife consume both plant and animals. They are also important in nutrient processing and energy transfer within the terrestrial environment and may serve as food resources for carnivores. Most mammalian and avian species are not strict insectivores or herbivores and instead consume both plant and animal matter usually depending upon the availability of food resources. For risk assessment purposes for evaluating contaminant exposures, mammals and birds are classified into these general groups based on their primary food types. Otherwise most animals would be classified as omnivores.

- *Carnivorous Wildlife* – Carnivorous mammals and birds consume primarily other mammals and birds. Carnivores are important in the control of rodents and other small mammals with high reproductive capacities.

- *Aquatic Invertivores* – Aquatic invertivores are mammals and birds that consume primarily aquatic invertebrates. These organisms are important in the nutrient processing and energy transfer between the aquatic and terrestrial environments. Some avian and bat species consume primarily emerging insects and are important in the control of these populations.

- *Piscivores* – Piscivorous mammals and birds consume primarily fish. These organisms are important in the nutrient processing and energy transfer between the aquatic and terrestrial environments.

3.4 Exposure Pathways of Chief Concern

Fish

The primary exposure pathway for fish is direct contact with contaminants in surface water. This is applicable to both asbestos and non-asbestos contaminants. Fish may also be exposed to contaminants by ingestion of contaminated prey items, and incidental ingestion of sediment while feeding. Direct contact with sediment may also occur. This is often assumed to be minor compared to the pathways above.

Benthic Invertebrates

Benthic invertebrates may be exposed to contaminants in surface water and/or sediment via ingestion and/or direct contact. Benthic invertebrates may also be exposed to contaminants via ingestion of aquatic prey items that have accumulated contaminants in their tissues. This is applicable to both asbestos and non-asbestos contaminants.

Terrestrial Plants and Soil Invertebrates

Terrestrial plants and soil-dwelling invertebrates (e.g., worms) are exposed mainly by direct contact with contaminants in soil. Exposure of plants may also occur due to deposition of contaminated dust on foliar (leaf) surfaces, but this pathway is generally believed to be small compared to root exposure.

Mammals and Birds

Mammals and birds may be exposed to asbestos and non-asbestos contaminants via ingestion of soils, surface water, sediment and food. Mammals and birds may also be exposed to asbestos by inhalation exposures when feeding or foraging activities result in the disturbance of asbestos-contaminated soils, sediments or other media. Direct contact (i.e., dermal exposure) of birds and mammals to soils may occur in some cases, but these exposures are usually considered to be minor in comparison to exposures from ingestion (USEPA, 2003). Likewise, inhalation exposure to non-asbestos contaminants in airborne dusts is possible for all birds and mammals, but this pathway is generally considered to be minor compared to ingestion pathways (USEPA, 2003).

Amphibians

Amphibians (frogs, toads) inhabit both aquatic and terrestrial (mainly riparian) environments with early life stages being primarily aquatic and latter life stages primarily terrestrial. Amphibians in their early aquatic life stages may be exposed to contaminants in surface water via ingestion and direct contact. They may also be exposed to contaminants in sediment via ingestion and direct contact and to contaminants in aquatic prey items via ingestion. In the terrestrial (riparian) environment, amphibians may be exposed to contaminants in soils or sediments via ingestion, inhalation and/or direct contact and also as the result of ingestion of terrestrial prey items.

4.0 MANAGEMENT GOALS AND ASSESSMENT TECHNIQUES

4.1 Management Goals

Management goals are descriptions of the basic objectives which the risk manager wishes to achieve. The overall management goal identified for ecological health at the Libby OU3 site for non-asbestos contamination is:

> Ensure adequate protection of ecological receptors within the Libby OU3 Site from the adverse effects of exposures to mining-related releases of asbestos and other chemical contaminants to the environment. "Adequate protection" is generally defined as the reduction of risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota (USEPA, 1999).

In order to provide greater specificity regarding the general management goals and to identify specific measurable ecological values to be protected, the following list of sub-goals was derived:

- Ensure adequate protection of the aquatic communities in Rainy Creek, Fleetwood Creek, the Tailings Impoundment, the Mill Pond, the Carney Creek Pond, and Carney Creek from the adverse effects of asbestos and other site-related contaminants in surface water and sediment.

- Ensure adequate protection of terrestrial plant and soil invertebrate communities within the mined area from the adverse effects of asbestos and other site-related contaminants in soils.

- Ensure adequate protection of the mammalian and avian assessment populations from adverse effects of non asbestos contaminants in the mined area and the site drainages, and from the adverse effects of asbestos in the mined area, the site-related drainages and the surrounding forest area.

- Ensure adequate protection of the amphibian assessment population from adverse effects of asbestos and non asbestos contaminants in the mined area and the site drainages, and the surrounding forest area.

4.2 Definition of Population

A "population" can be defined in multiple ways. A common definition of the biological population by ecologists is: "A group of plants, animals and other organisms, all of the same species that live together and reproduce. Individual organisms must be sufficiently close geographically to reproduce. Sub-populations are parts of a population among which gene flow is restricted, but within which all individuals have some chance of mating any other individual" (Menzie et al., 2008). "Population" can also be defined differently in the context of a management goal. To prevent miscommunication in risk assessment and risk management, use of the term "assessment population" is recommended (USEPA, 2003). In problem formulation it is necessary to explicitly state the assessment population(s). The assessment population may be the same as the biological population as defined by ecologists or may be: 1) a component of the biological population (e.g., exposed population); or, 2) a component of relevant meta-population (e.g., a subpopulation).

For the Libby OU3 Site, the assessment populations are defined as the groups of organisms that reside in locations that have been impacted by mining-related releases. For exposure to non-asbestos contaminants, this is believed to be restricted to the mined area and the drainages associated with the mined area. For asbestos, the impacted area may also include surrounding forest lands that were impacted by airborne releases of asbestos. This information will be based on results of the RI, including the spatial pattern of asbestos contamination in forest soils and tree bark.

4.3 Assessment Endpoints

Assessment endpoints are explicit statements of the characteristics of the ecological system that are to be protected. Because the risk management goals are formulated in terms of the protection of populations and communities of ecological receptors, the assessment endpoints selected for use in this problem formulation focus on endpoints that are directly related to population stability. This includes:

- Mortality
- Growth
- Reproduction

Other assessment endpoints may be appropriate, if it is believed that the endpoint can be related to population stability. For example, carcinogenicity might be of concern if it could influence the reproductive potential of a species over its lifetime.

4.4 Measurement Endpoints

Measurement endpoints were initially defined by EPA guidance to represent quantifiable ecological characteristics that could be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA 1992, 1997). The term measurement endpoint was later replaced with the term *measures of effect* and was supplemented by two other categories of measures (USEPA, 1998). This problem formulation still uses the term measurement endpoint to describe both measures of exposure and effect.

There are a number of different techniques available to ecological risk assessors for measuring the impact of site releases on assessment endpoints and assessing whether or not risk management goals are achieved. The strategies that are available for use at this site are discussed below.

1. The Hazard Quotient (HQ) Approach

A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor to a "benchmark" that is believed to be without significant risk of unacceptable adverse effect:

HQ = Exposure / Benchmark

Exposure may be expressed in a variety of ways, including:

- Concentration of a contaminant in an environmental medium (water, sediment, diet and soil)
- Concentration of a contaminant in tissue
- Amount of a contaminant that is ingested by a receptor

In all cases, the exposure and benchmark must be expressed in like units. For example, exposure in surface water (mg/L) must be compared to a benchmark in mg/L. If the value of an HQ is less than 1E+00, risk of unacceptable adverse effects in the exposed individual is judged to be acceptable. If the HQ exceeds 1E+00, the risk of adverse effect in the exposed individual is of potential concern.

However, not all HQ values are equally reliable as predictors of effect. Interpretation of the ecological consequences of HQ values that exceed 1.0 depends on the species being evaluated and on the toxicological endpoint underlying the toxicity benchmark. In most cases, the benchmark values used to compute HQ values are not based on site-specific toxicity data, and do not account for site-specific factors that may either increase or decrease the toxicity of the metals compared to what is observed in the laboratory. In addition, benchmark values are often not available for the species of feeding guild of concern, so values are extrapolated from other similar types of receptors. Consequently, most HQ values should be interpreted as estimates rather than precise predictions.

2. Site-Specific Toxicity Tests (SSTT)

Site-specific toxicity tests measure the response of receptors that are exposed to site media. This may be done either in the field or in the laboratory using media collected from the site. The chief advantage of this approach is that site-specific conditions which can influence toxicity are usually accounted for, and that the cumulative effects of all contaminants in the medium are evaluated simultaneously. One potential limitation of this approach is that, if toxic effects are observed to occur when test organisms are exposed to site media, it ~~is usually~~ may not be possible to specify which contaminant or combination of contaminants is responsible for the effect without further testing or evaluation. A second limitation is that it may be difficult to perform tests on site samples that reflect the full range of environmental conditions which may occur in the field across time and space.

3. Population and Community Demographic Observations (PCDO)

Another approach for evaluating possible adverse effects of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors (e.g., plants, benthic organisms, birds) is different than expected. The chief advantage of this approach is that direct observation of community status does not require making the numerous assumptions and estimates needed in the HQ approach. However, there are also a number of important limitations to this approach. The most important of these is that both the abundance and diversity depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes quite difficult to locate reference areas that are truly a good match for all of the important habitat variables at the site, so comparisons based on this approach do not always establish firm cause-and-effect conclusions regarding the impact of environmental contamination on a receptor population.

4. *In-Situ* Measures of Exposure and Effects (IMEE)

An additional approach for evaluating the possible adverse effects of environmental contamination on ecological receptors is to make direct observations on receptors in the field, seeking to identify if individuals have higher exposure (tissue) levels, observed lesions and/or deformities that are higher than expected. This method has the advantage of integrating most (if not all) factors that influence the bioavailability of contaminants in the field. The limitations of this method may be in the interpretation of the consequences of the measured exposure or effect (if suitable toxicity information are not available) and if an appropriate reference population for comparison is available.

It is important to note that the choice of which one or more of these basic approaches is needed or useful in the assessment process may vary between sites, receptors groups, and contaminant types. Section 5 presents the sequence of assessment steps that will be used to evaluate risks to ecological receptors from non-asbestos contaminants, and Section 6 describes the strategy that will be used to evaluated ecological risks from asbestos.

5.0 ASSESSMENT OF RISKS FROM NON-ASBESTOS CONTAMINANTS

5.1 Overview of the Assessment Strategy

missing important figure

Figure 5-1 provides a flow diagram that outlines a basic strategy that is often used to assess risks ~~from~~ non-asbestos contaminants to terrestrial receptors (plants, wildlife) at a site and to aquatic receptors (fish, invertebrates) in the surface water drainages associated with a site. Each of the steps is described below.

Toxicity Assessment

The first step in the assessment of each contaminant is usually to determine if a relevant and appropriate benchmark or toxicity reference value (TRV) exists for the chemical. If so, the chemical is typically carried to the initial HQ Sceening step (below). If there is no benchmark or TRV available, the next step is often to determine if the chemical is present at levels similar to an appropriate background or reference area. If so, no further assessment is needed. If the chemical is present at a level that appears to be elevated over background, then the chemical may be evaluated using one or more non-HQ lines of evidence, or may be identified as a source or uncertainty.

Initial HQ Screen

For non-asbestos analytes that have an appropriate benchmark or TRV, the HQ approach is usually the first line of assessment for all receptor groups. This step begins with a screening-level HQ assessment for each analyte in each medium. In this step, a maximum HQ value (HQmax) is calculated for each medium for each receptor group exposed to the medium, based on the highest detected level of each chemical in each medium. If the maximum concentration does not exceed 1.0, it is normally concluded that risks from that chemical in that medium to that receptor group are of minimal concern and that further assessment is not required.

Refined Screen

If the potential for concern for a chemical in a medium can not be excluded based on the initial HQ screen, then a refined HQ screen is usually performed next. This typically includes recalculation of HQ values based on a refined estimate of the exposure concentration (rather than just a maximum value), as well as use of refined receptor-specific exposure parameters and toxicity values (when available). The refined screen results are normally evaluated by considering the frequency and magnitude of HQ exceedences, and by reviewing the spatial pattern of exceedences. If the magnitude and frequency of HQ exceedences is low, and the data do not suggest there are any localized areas of concern, then further assessment will generally not be required.

Comparison to Background

If further assessment is required, the concentration levels seen in site samples may be compared using appropriate statistical methods to concentrations that are judged to be representative of background (natural) conditions in the area. This is most important for metals, since metals occur naturally in soil and water. It may also be useful for some organic compounds that occur naturally (alkanes, PAHs, etc.). If site levels appear to be similar to natural background levels, further assessment is usually not required. If site levels appear to be elevated above natural background, the further assessment may be warranted, as described below.

Other Lines of Evidence

If the potential for concern for a chemical in a medium can not be excluded based on the steps above, then the utility of obtaining data from other lines of investigation will be considered. This may include site-specific toxicity tests and/or community surveys. These tests, if needed, are most likely to be useful for evaluation of risks to fish from surface water, risks to benthic invertebrates from sediment, and risks to plants and soil invertebrates from soil. Further assessment of risks to wildlife receptors, if needed, may conceptually use the same techniques (site-specific toxicity testing, community surveys), although implementing these techniques for wildlife is somewhat more difficult for birds and mammals than for aquatic receptors.

5.2 Initial Screen Results Based on Phase I Data

As noted in Section 2, one round of environmental sampling (referred to as Phase I) of surface water, sediment and on-site soils has been completed at the site in the fall of 2007. These data include measurements of a wide range of non-asbestos analytes, including metals, VOCs, SVOCs, PAHs, PCBs, pesticides, radionuclides, nitrogen compounds, and anions.

It is important to note that the Phase I data alone are not considered sufficient to support the HQ-based assessment steps or background comparison step shown in Figure 5-1 because the data represent only one point in time, and may not fully capture either temporal or spatial variability at the site. For this reason, final implementation of the assessment process will not be performed until two additional rounds of environmental data (scheduled for collection in the spring and summer of 2008) are collected.

Nevertheless, the Phase I data are sufficient to provide an initial impression regarding the potential for concern from non-asbestos contaminants at the site. The results of the initial screening step performed on the Phase I data are presented below.

Surface Water

An initial screening for chemicals of potential concern (COPCs) in surface water was completed by comparing the highest measured concentration of a chemical in surface water to available aquatic toxicity screening benchmarks. The selected screening benchmarks are described in detail in Attachment C and are listed in Table 2-15. All maximum detected concentrations of metals are lower than respective benchmarks. Benchmarks are not available for either volatile or extractable hydrocarbons. These were detected at three sampling locations two of which are on seeps at Carney Creek (CCS-14 and CCS-11; Figure 2-8) and one is on Fleetwood Creek (FC-2; Figure 2-8).

Sediment

An initial screening for COPCs in sediments was completed by comparing the highest measured concentration of a chemical in sediment to respective sediment toxicity screening benchmarks. The selected screening benchmarks are described in Attachment C and are listed in Table 2-20. Maximum detected concentrations of aluminum, chromium, iron, lead, manganese, nickel, selenium and pyrene exceed respective screening benchmarks based on Threshold Effect Concentrations (TECs), and maximum detected concentrations of chromium, manganese and nickel also exceed respective benchmarks based on Probable Effect Concentrations (PECs). Benchmarks are not available for either volatile or extractable hydrocarbons.

Mine Waste and Soils

An initial screening for COPCs in soils was completed by comparing the highest measured concentration of a chemical in mine waste or soil with respective to available toxicity screening benchmarks for plants, soil invertebrates and wildlife. The selected screening benchmarks are described in detail in Attachment C and are listed in Table 2-23.

For terrestrial plants, mean and maximum detected concentrations of cobalt, copper, manganese, nickel and vanadium are higher than respective toxicity screening benchmarks. For soil invertebrates, the maximum detected concentration of manganese is higher than the toxicity screening benchmark. For wildlife, the mean and maximum detected concentrations of chromium, copper, lead and vanadium are higher than respective toxicity screening benchmarks. The maximum detected concentrations of nickel and zinc also exceed respective benchmarks. All other maximum detected concentrations are lower than respective benchmarks. Benchmarks are not available for either volatile or extractable hydrocarbons or methyl acetate.

Summary

Based on the first round of data collected in the fall of 2007, it is tentatively concluded that risks to ecological receptors are likely to be low for most non-asbestos contaminants, although a few contaminants may be of potential concern and require further assessment. Final decisions about which non-asbestos contaminants may be excluded in the initial screen and which require further assessment will be made after receipt of two additional rounds of data from the spring and summer of 2008.

6.0 ASSESSMENT OF RISKS FROM ASBESTOS

Asbestos is the generic name for the fibrous habit of a broad family of naturally occurring poly-silicate minerals. As noted previously, the Libby vermiculite deposit contains a mixture of amphibole asbestos types, referred to as Libby Amphibole Asbestos (LA). Attachment D provides a review of asbestos mineral logy, fate and transport, analytical measurement techniques, and toxicity.

6.1 Overview of the Assessment Strategy

Conceptually, the process of assessing ecological risks from asbestos might follow the same procedure as used for non-asbestos contaminants (see Figure 5-1). As noted previously, this approach depends upon the availability of relevant and reliable toxicity reference values or benchmarks for the contaminants of potential concern.

However, in the case of asbestos, no toxicity benchmarks have been derived to date for any receptor class, and most of the studies that are available that might potentially serve as a basis for a benchmark are based on studies of chrysotile asbestos rather than amphibole asbestos. In particular, there are no studies on the toxicity of LA on any class of ecological receptors. Because of this, it is concluded that available data are not sufficient at present to employ an assessment strategy that is HQ-based. Rather, the it is concluded that strategy for assessing risks from asbestos must be based on information that can be collected from field studies of the following types:

- Site-specific toxicity testing
- Site-specific population surveys
- Site-specific studies of biomarkers of exposure and effect

The assessment strategies that are considered most likely to be useful for aquatic receptors, terrestrial plants and soil invertebrates, and terrestrial wildlife (birds, mammals) are discussed in the following sections.

6.2 Strategy Options for Assessing Risks to Aquatic Receptors

Site-Specific Toxicity Testing of Surface Water

One of the most direct methods for evaluation of risks to aquatic receptors is site-specific toxicity testing. Figure 6-1 provides a conceptual flow diagram of the approach for surface water.

Step 1. Collect surface water at a location and at a time when the concentration of LA is expected to be near a maximum value for the site.

Step 2. Evaluate the toxicity of the water in the undiluted state, and after a series of dilutions to an appropriate aquatic species (e.g., rainbow trout) of an appropriate age class (e.g., larvae). Endpoints include mortality, growth, and behavior.

Step 3. If adverse effects are noted for one or more endpoints, use the data to estimate a site-specific exposure-response curve. In addition, preserve the fish for a study of histological lesions and potentially also tissue burden (fibers/gram tissue). These data will help establish a firm foundation for extrapolation of exposure response data from the laboratory to the field.

If no toxicity is observed in the undiluted site water, it may be necessary to perform a study in which LA is added to water to yield concentrations even higher than achieved in the site waters. The purpose of this would be to establish an estimate of the effect level. If toxicity is seen in this spiking study, the data can be used to derive a site-specific exposure-response curve for LA. As above, this study would also include collection of data on tissue burden and histopatholgical lesions in the exposed organisms.

This approach has been used by Belanger (1985) to study the toxicity of chrysotile on several species of aquatic receptors.

Site-Specific Toxicity Testing of Sediments

Site-specific toxicity testing is also a direct and often useful approach for evaluating risks to benthic macroinvertebrates from sediments. Figure 6-2 provides a conceptual flow diagram for how this may be done. As shown, the approach is similar to that for surface water, except that a dilution series may not be needed because sediments could be collected from a range of locations that span a wide range of concentrations. Endpoints usually include growth and survival, and may include reproduction in some cases

Population and Community Demographic Observations

Another line of evidence for evaluation of risks for aquatic receptors is the collection of data on the density and diversity of receptors (fish and/or benthic organisms) in site waters and comparison to appropriate reference locations. If this line of evidence is selected for implementation, it is expected that the collection of population and community demographic information would be performed approximately as follows:

Benthic Invertebrate Community. Benthic invertebrate community structure and function would be measured at a number of different on-site stream locations (e.g., upper and lower Rainy Creek, Carney Creek and Fleetwood Creek). Benthic invertebrate samples would be collected at the same locations as sediment and surface water samples to facility an analysis of the correlation between community status and contaminant level. Samples would be collected according to an established EPA *Rapid Bioassessment Protocol*

(RBP) (USEPA, 2003). For each sampling location, a number of alternative metrics of benthic community status would be calculated and combined to yield a Biological Condition Score. A number of alternative measures of habitat quality would also be measured to yield a Habitat Quality Score (a comparison of the Biological Condition Score to the Habitat Quality Score provides information on the likely contribution of non-habitat factors (e.g., chemical pollution) on the benthic community). The scores and individual metrics would be examined to identify if the community is impacted relative to reference and if there are any apparent trends in condition with asbestos concentrations. This method does require the selection of at least one appropriate reference area for comparison. The reference area(s) should match as closely as possible the habitat variables present at the aquatic sites being evaluated. Note that, because asbestos contamination may have been transported by air from the mine site area to upstream locations along Rainy Creek, upstream locations may not be an appropriate reference.

Fish Community. Fish community surveys are usually performed at selected locations along site streams using standard electrofishing techniques. Fish species and number (density) are noted and compared to matched reference locations.

In-Situ Measures of Exposure and Effects

Another line of evidence that may be useful is the examination of fish collected from the site and reference areas to assess the level of exposure via measures of asbestos body burden, and the level of effect via the frequency and severity of histological lesions. This would normally be implemented simply by selecting fish that are captured by the electroshocking technique used to perform the fish community survey, and preserving these for potential future analysis.

Tissue Burden

Measurements of LA tissue burden in fish could be performed on whole body and/or on selected organs (e.g., gill, kidney, etc.). Tissue to be analyzed would be weighed (wet weight) and then dried and ashed. The ashed residue would be resuspended in acid and water and an aliquot deposited on a filter for analysis by TEM. Results would be expressed as fibers of LA per gram (wet weight) of tissue.

Gross and Microscopic Lesions

Fish collected from the field and reference locations may be examined for gross pathology, pathological effects, and histological effects. Lesions that have been reported in the literature following exposure of aquatic organisms to asbestos are summarized in Table 6-1. If this approach is implemented, the incidence and severity of effects observed in fish from on-site locations would be compared to that observed in organisms collected from an appropriate reference area, and also to the concentrations of asbestos in surface water and sediment at the sampling stations in an effort to establish a dose-response relationship. Consequences of the measured pathology effects would be evaluated based on literature information that associates the pathology effects with adverse effects on growth reproduction and survival. However, the evaluation of ecological consequences may be limited by the small number of samples available.

6.3 Strategy for Assessing Risks to Terrestrial Plants and Soil Invertebrates

For the purposes of assessing risks to terrestrial plants and soil-dwelling invertebrates (e.g., worms), it is expected the site will be divided into two main parts: the on-site mined area and the surrounding forested area. It is not expected that an assessment would be performed on the mined area because the mined area has been and continues to be disturbed by heavy machinery, as well as the placement of piles of waste rock that are unlikely to be suitable for plant growth. If an evaluation of LA toxicity is needed in on-site soils, this would be undertaken at the level of the Feasibility Study (FS). The approaches that are available for evaluating risks to plants and soil invertebrates in the forest area surrounding the site are presented below.

Site-Specific Toxicity Testing

As above, one of the most direct ways for assessment of risks to terrestrial plants and soil invertebrates in off-site soils is site-specific toxicity testing of soils collected from areas near the mined area. The exact choice of test soils would be based on the Phase I forest soil data (see Figure 2-14), and would, to the extent possible, include a range of LA levels from ND (not detected) to the highest values observed. Testing would be completed using standard laboratory test organisms using established protocols for chronic endpoints (growth, reproduction and survival). If toxicity is observed, the data would be used to derive site-specific toxicity values for plants and soils invertebrates for LA.

Site-Specific Population and Community Demographic Observations

For soil invertebrates, methods for measurement of community demographic information are not very well established, and the results are often difficult to interpret, especially for U.S. western soils. Therefore, it is considered likely that this assessment tier will not be implemented for soil invertebrates.

In contrast methods are well established for assessment of the density and diversity of terrestrial plant communities, and application of these methods may be useful for evaluating whether plant communities near the mine area are observably different that in appropriate reference locations.

6.4 Strategy for Assessing Risks to Terrestrial Birds and Mammals

Asbestos is found in soils across the mine site area, as well as in the surface waters and sediments of the Rainy Creek drainage. Tree bark data from Phase I suggest that asbestos also contaminates trees in forested areas for some distance away from the mine site.

Include Duff?

Wildlife species in the forested area may be exposed to fibers by a variety of pathways, including both oral and inhalation routes. The relative magnitude of exposure for the two exposure routes is not known.

Biomarkers of Exposure and Effect

At present, one of the few lines of evidence available to evaluate risks to wildlife from asbestos is the measurement of biomarkers of exposure and effect in organisms collected from the site. This technique has the advantage that it allows an assessment of exposure and effects by both oral and inhalation exposures, and may allow development of maps that indicated the relative levels of exposure as a function of location. The chief disadvantage of this method is that biomarkers of exposure and effect are not easy to extrapolate to effects on growth, reproduction and survival, and hence on population stability.

Indicator Species

In order to implement this approach, it is first necessary to identify the classes of wildlife that are likely to be maximally exposed. The most important selection criteria include the following:

- Non-transitory. Some organisms migrate over long distances, and are present in the area of the site for only a short time each year. Because of the brief interval they would be exposed, such organisms would have less exposure than organisms that are present year round or for most of the breeding season.

- Small home range. Organisms that have a large home range are likely to spend a small part of their time in and about the most heavily impacted areas of the site. Consequently, they are likely to be less exposed than organisms that have a small home range and spend a high fraction of their time in and about the impacted areas.

In addition to these two baseline factors, there are a number of other factors that may also influence the relative level of exposure, including the following:

- Foraging strategy – Species that forage on the ground and have a greater potential to disturb asbestos fibers are expected to have more inhalation exposure than those that forage in shrubs or tree foliage. Species that feed in flight on insects and carnivores that prey on other mammals and birds are expected to be less exposed. Species that forage on aquatic organisms and fish would also be less exposed because inhalation exposures require the disturbance of fibers which is less likely under wet conditions.

- Habitats and Nesting – Where species find shelter, give birth (or nest) and/or rear young may also influence exposures. Many species burrow into the ground or create shallow runs under forest litter. Some others will create nests/dens in existing cavities of barren rock or dead trees. Burrowers are expected to receive higher exposures compared to those species that live higher in trees.

- Body Size – Ingestion rates and breathing rates per unit body weight tend to be higher for species with small body weights compared to species with higher body weights. Thus, exposure by both oral and ingestion pathways may be highest for small receptors.

- Longevity In humans, it is well established that risk of adverse effects is a function of cumulative exposure. That is, risk depend both on exposure level and also on exposure duration. For this reason, organisms that have longer life spans will tend to have higher cumulative exposures and hence may be more likely to display adverse effects from asbestos exposure.

Taking these factors into account, the feeding guilds and species identified as residing within the area of Libby OU3 (listed in Attachment A) were evaluated in order to identify a list of receptors most likely to have high exposures to LA, as follows:

1) Species inhabiting terrestrial and riparian habitats were segregated into two groups based on habitat type (terrestrial and riparian).
2) Because exposures to asbestos for species inhabiting riparian habitats are expected to be primarily related to ingestion of aquatic food items as well as surface water and sediments, the riparian species were segregated into two exposure groups by feeding guild. These include aquatic invertivores/omnivores and piscivores.
3) For species that inhabit terrestrial habitats, those that forage on the ground and or inhabit nests or burrows were identified from the larger list and classified into a "ground" foraging group. These species are expected to be the highest exposed to asbestos via inhalation and ingestion as a result of probing and disturbing asbestos in soils and ground litter.
4) Species that forage primarily in trees and shrubs were identified from the larger list and classified as an "arboreal" foraging group. These species may be exposed to asbestos on tree bark or leaf surfaces as result of foraging for food.
5) Carnivorous species were identified and placed in separate group based on feeding guild. These species are expected to be exposed to asbestos primarily via ingestion and inhalation exposures are expected to be lower than those species that forage on the ground for food.
6) The ground and arboreal groups were further stratified into feeding guilds (invertivore, grainivore, omnivore, carnivore) to reflect exposures related to ingestion.
7) The species in each group were then reviewed further and those with small home ranges and small body sizes were selected preferentially. These species are expected to be maximally exposed to asbestos impacted area and will not range in and out of the area.
8) For avian species, birds that are transients (occurring at the site only during spring or fall migrations) were excluded, while birds that are resident year round or are present for extended periods during the warm weather were retained.

Table 6-2 provides the list of species that meet the selection criteria above. The following table summarizes the categories of receptor groups that are likely to be maximally exposed in each exposure area.

Location	Exposed Receptor Group	Exposure
Mined area and Forest area	Ground Invertivore	Ingestion of asbestos in soil invertebrates and inhalation of asbestos in soil during disturbance.
	Ground Herbivore/Omnivore	Ingestion of asbestos in/on plant material and inhalation of asbestos in soil during disturbance.
Forest area	Arboreal Invertivore	Ingestion and inhalation of asbestos on tree bark and/or vegetation.
Riparian area	Aquatic Invertivore/Omnivore	Ingestion of asbestos in aquatic plants and aquatic invertebrates.
	Piscivore	Ingestion of asbestos in fish.

Measurement of Asbestos Tissue Burdens

If this approach is implemented, asbestos tissue burdens in selected organs (lungs and gastrointestinal tract) of animals collected at the site would be analyzed for asbestos tissue burden. Tissue burden in lung will be interpreted as an indication of inhalation exposure, and tissue burden in the GI tract and kidneys will be taken as an indication of oral exposure. Comparison of the data from on-site locations and reference locations would be used to establish an empiric estimate of the spatial extent where LA exposures can be recognized as being higher than background.

Histopathology

A large number of studies have been performed in mammals to identify the effects of inhalation exposure to asbestos on the respiratory tract, and, to a lesser degree, the effects of inhalation and ingestion exposure on other organs (e.g. gastrointestinal tract). In animals, histological signs of tissue injury can be detected at the site of deposited fibers within a few days (ATSDR 2001). Ingestion exposures have been associated with lesions in the parathyroid tissue, brain tissue, pituitary tissue, endothelial tissue, kidney tissue, and peritoneum tissue (Cunningham et al., 1977). Induction of aberrant crypt foci in the colon (Corpet et al., 1983) and tumors of the gastrointestinal tract have also been reported. Inhalation exposures are associated with fibrosis, lung tumors and lesions along the respiratory bronchioles, alveolar ducts, alveoli, and lung tissue (McGavran et al. 1989; Donaldson et al. 1988; Davis et al., 1980a, 1980b, 1985, 1986). Mesotheliomas have been observed (Davis and Jones 1988, Davis et al. 1985, Wagner et al. 1974, 1980, Webster et al. 1993). The histopathological effects of asbestos exposures in avian species is not known.

If this line of evidence is pursued, organisms collected from site locations (on-site, forest area, riparian area) will be examined for gross and microscopic pathological effects. The incidence and severity of effects observed will be compared to organisms from suitable reference areas, and will also be correlated with the relative concentrations of LA in the collection area. These data, combined with the tissue burden data, will help define the spatial extent of LA contamination that can impact wildlife. Interpretation of the ecological consequences of any gross or histological lesions that are observed will be based on literature information that associates the pathology effects with adverse effects on growth, reproduction, and survival, as well as on consultation with experts in the field.

Population and Community Demographic Observations

Quantitative surveys of mammalian and avian density and diversity are difficult to perform because of the high natural variability in receptor density over space and time. For this reason, it is not expected that formal population surveys will be attempted at this time. However, semi-quantitative data in the form of number of organisms of each species collected per trapping day will be available from the field collection effort for both on-site locations and reference locations. Comparison of these trapping rates will provide an initial impression as to whether population densities are likely to be similar or dissimilar in site areas compared to reference areas. If evidence of an apparent difference is obtained, this may be followed with more quantitative efforts to compare population demographics, depending on the overall weight of evidence available.

Additional Toxicity Testing with LA

Based on the results of the lines of evidence described above, further studies of LA exposure and effect in birds and/or mammals may be considered. This testing may be used to identify dose-response values for growth, reproduction or survival effects in birds or evidence of physiological stress.

6.5 Strategy for Assessing Risks to Amphibians

Site-Specific Toxicity Testing

One option for the assessment of risks to amphibians from contact with site surface water is be site-specific toxicity testing. If selected for implementation, the test would be performed approximately as follows:

Step 1. Collect surface water from multiple on-site locations focusing on ponded areas and seeps where amphibians are expected to occur.

Step 2. Evaluate the toxicity of each site collected water (undiluted)

Step 3a. If toxicity is seen in one or more waters, use the data to estimate a site-specific exposure-response curve. In addition, select the water with the highest toxicity (highest concentration) and repeat the toxicity tests on a dilution series of that water.

Step 3b. If no toxicity is observed in any site water, consider perform a "spiking" study in which LA is added to water to yield concentrations even higher than achieved in the site waters. If toxicity is seen in this spiking study, the data can be used to derive a site-specific exposure-response curve for LA.

Amphibian toxicity studies are often conducted using *Xenopus lavis* as described in ASTM E1439-98(2004) Standard Guide for Conducting the Frog Embryo Teratogenesis Assay-*Xenopus* (FETAX). If implemented, it is considered likely that it would be appropriate to extend the normal duration of the study (4 days) to 14 days to allow a longer period of exposure and observation of development. Endpoints evaluated in the study would include mortality, malformations, growth, and development.

The line of evidence for assessment of risks for amphibians to LA in sediment will also be site-specific toxicity testing. The approach is similar to that for surface water, except that the site-specific exposure response curve can be developed based on the site samples with a dilution series because the samples selected for testing can be chosen to reflect the range of values seen on-site, from lowest to highest.

In-Situ Measures of Exposure and Effects

A second line of evidence available for assessment of risks to amphibians from LA in surface water and sediment would be the collection of amphibians from the site and from reference areas to examine and assess the frequency and severity of gross and histological abnormalities. This examination could be based on field observations alone, or could include laboratory-based examination of some species. If this line of evidence is implemented, the incidence of effects observed in amphibians collected from the site would be compared to a reference area as well as regional and national statistics in order to judge if there is an effect. If so, the incidence of abnormalities would be correlated with the concentrations of LA in surface water and sediment at the sampling stations in an effort to establish a dose-response relationship.

Population Survey

The USFWS has developed standard methods for studies of the amphibian (frog) communities in the field based on detection of the number and type of calls. Based on this approach, a trained observer can identify both the number of species (diversity) and the number of individuals (density) of frogs in an area, and this may be compared to expected values observed at other suitable reference locations.

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TABLES

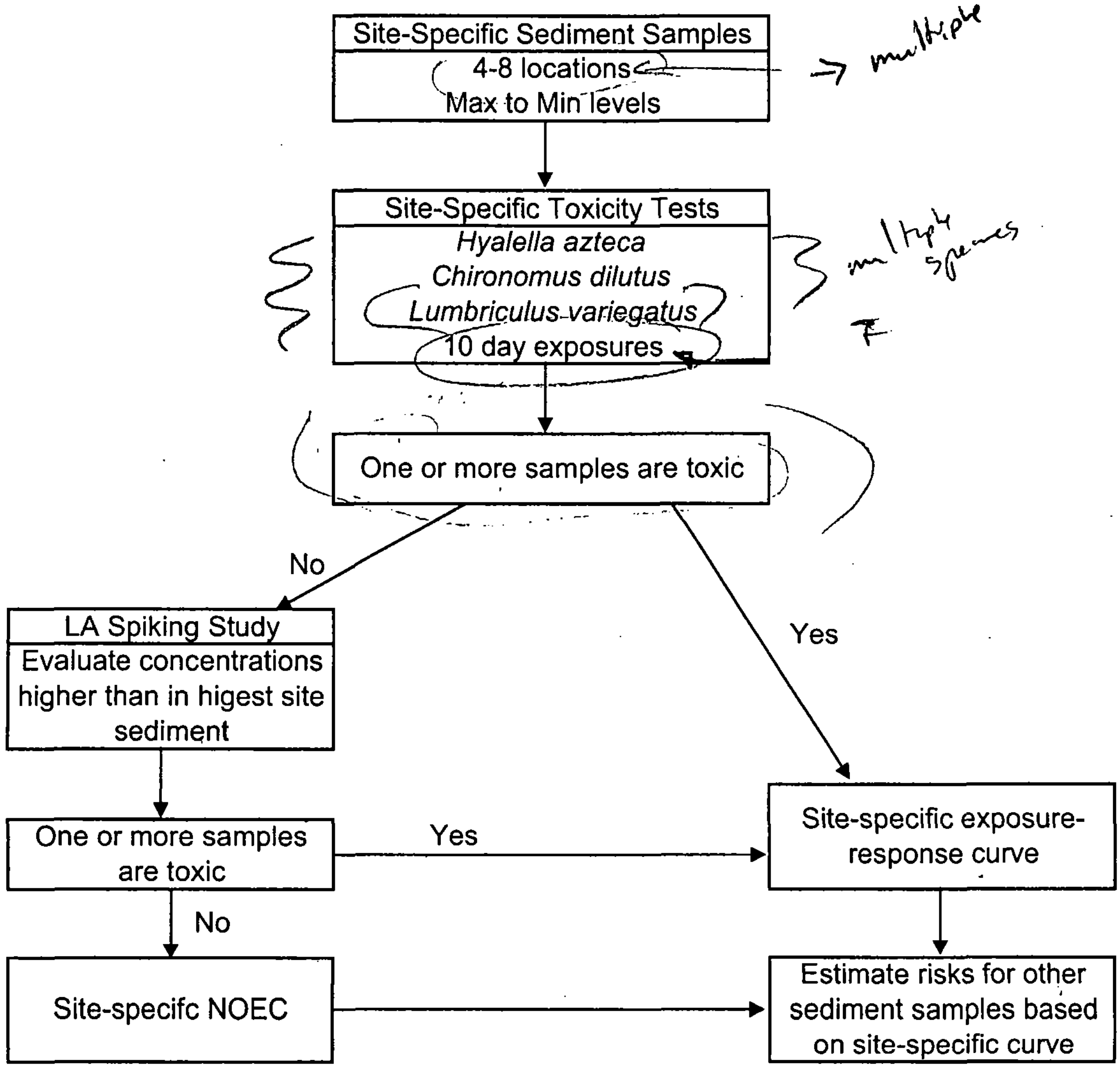
Table 2-9. Asbestos Results for Sediment

Reach	Station	Index ID	RESULTS		
			$MF_{LA\%}$ fine	$MF_{LA\%}$ coarse	
Upper Rainy Creek	URC-1	P1-00409	ND	--	0-2"
	URC-2	P1-00408	<1%	Tr	0-2" ← soil?
Tailings Impoundment	TP	P1-00407	<1%	Tr	0-4"
	TP-TOE1	P1-00326	2%	0.38%	0-2"
	TP-TOE2	P1-00325	3%	0.03%	0-2"
Mill Pond	MP	P1-00348	<1%	--	0-2"
Lower Rainy Creek	LRC-1	P1-00338	<1%	0.13%	0-2"
	LRC-2	P1-00336	<1%	Tr	0-2"
	LRC-3	P1-00335	2%	--	0-1"
	LRC-4	P1-00329	<1%	--	0-2" - lots of sediment
	LRC-5	P1-00328	<1%	Tr	0-1"
	LRC-6	P1-00327	<1%	--	0-1"
soil?	* FC-2	P1-00406	Tr	ND	0-4" - stream bank
Fleetwood Creek	FC-Pond	P1-00405	<1%	--	0-4" soft Bottom
Soil	* FC-1	P1-00404	ND	ND	0-4" - stream bank smpl
Carney Creek	CC-2	P1-00399	<1%	0.20%	0-2"
	CC-1	P1-00395	4%	0.52%	0-2"
Seeps	CCS-9	P1-00400	7%	Tr	0-4"
	CCS-8	P1-00398	6%	0.41%	0-6"
	CCS-6	P1-00397	2%	Tr	0-6"
	CCS-1	P1-00396	2%	Tr	0-4"
	CCS-11	P1-00402	<1%	0.20%	0-4"
	CCS-14	P1-00403	<1%	Tr	0-4"
	CCS-16	P1-00289	4%	--	0-4"

ND = not detected
Tr = trace
MF = mass fraction
-- = coarse fraction was not analyzed.

Doesn't match SAP?

FIGURE 6-2
STRATEGY FOR SITE-SPECIFIC TESTING OF
RISKS TO BENTHIC INVERTEBRATES FROM ASBESTOS IN SEDIMENT



→ multiple

multiple species

Cut back
LA focus only
2-3 samples ALA Flow metals
& Availability of Reference

1&2A